CS425FZ (Audio & Speech Processing)

Assignment 1

(Value 20%)

Joseph Timoney
Joseph.Timoney@mu.ie

Inbarasan Muniraj
inbarasan.muniraj@mu.ie

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This is an open-book, graded assignment that may be completed in groups of up to three students, with one submission per group. Students must not directly reuse or replicate solutions from online sources, previously submitted coursework, or AI-generated content. Any violation of this rule, even for a single question, will result in a zero mark for the entire assignment and may be reported to the Executive Vice-Dean of MIEC and/or the Maynooth University Plagiarism Board. All submissions will be subjected to similarity checks to identify plagiarism or inappropriate collaboration, and the Turnitin tool available through Moodle can also detect AI-generated content. The lecturer reserves the right to interview students or groups regarding their submission in special cases, particularly where academic integrity concerns arise. All external sources, datasets, and references used must be properly cited in the submission.

The objective of this assignment is to demonstrate an understanding of digital waveforms, Fourier analysis, and time–frequency representations using the FFT and spectrogram. Students are required to use Java, Processing, Python, or Octave/MATLAB to prepare a narrative analysis explaining how these signal-processing techniques work. All results must be presented in a PowerPoint presentation, where each plot clearly illustrates the shape of the waveform and includes an appropriate title, labelled axes, and a descriptive caption. Along with each plot, a corresponding sound file must be embedded in the slide, imported as an MP3 file to minimise file size. For every plot, the following slide must contain the complete programming script used to generate the waveform and its graph. Audio files may be generated programmatically, recorded by the student, or sourced externally, provided that proper references are included. Note: Java and Processing only handle 16-bit mono WAV files properly. If your file is not in that format, use Audacity to split a stereo track to mono and export it as a 16-bit WAV.

Waveforms

1. Generate and plot one example of the waveform of a sinusoid at a frequency, amplitude, and phase of your choice. Show the waveform from time t=0. Select the frequency of the sine wave from the set of musical notes of your choice. Make sure to give the frequency of the wave in the title of the plot.
2. Generate and plot an example of waveforms composed of sinusoids at harmonically related frequencies to create either a sawtooth wave, a square wave, or a triangle wave.
3. Read in a WAV file of an “effect”/natural sound and plot only 20 seconds of it.
4. Read in a WAV file of a Speech utterance (it could be from the web or recorded by yourself) and plot it (approx. 2-5 seconds), put the text of the utterance in the title of the plot.

Fourier transform

5. Plot the magnitude of the Fourier transform (FFT) of a signal composed of more than one sinusoid of different frequencies and amplitudes using a rectangular and Hanning window. Use an FFT length of N=256 and then N=2048.
6. Record at least 1 second of you saying any vowel sound using Audacity or an equivalent software. Use the editor to retain only the steady portion of the vowel waveform. Plot the magnitude of the Fourier transform of this, picking a suitable value for N (e.g., 256, 512, 1024, 2048) so that it is easy to identify at least two formant peaks from the spectrum.

Spectrogram

7. Plot the spectrogram of the speech waveform you used earlier for a short window N=256 and a long window N=1024. Identify the voiced and unvoiced speech in the plot.
8. Plot the spectrogram of a sound effect that has distinctive frequency components, e.g., a bird sound, a chainsaw, a car starting, clock strike. Pick an appropriate window length for the frequency components to be clearly displayed. Make sure to mention the window length in the title of the plot.
9. Plot the spectrogram of a short drum loop of your choice with N=256 and N=2048 to show that the shorter window means a better time resolution, and thus, the points in time of the drum hits are easier to discern. Point this out in the figure in its caption.

Sampling and Aliasing

10. Generate a sinusoidal signal at a fixed frequency selected from the set of musical notes of your choice. Sample the signal at three different sampling frequencies: one well above the Nyquist rate, one close to the Nyquist rate, and one below the Nyquist rate. Plot the time-domain waveform and the magnitude of the Fourier transform for each case. Clearly illustrate and explain the effects of aliasing in both the time and frequency domains. Insert an audio playback of each sampled signal and describe the audible differences in the caption.

Sources of sound files

- https://freesound.org/
- BBC sound effects: https://sound-effects.bbcrewind.co.uk/search
- Musicradar https://www.musicradar.com/news/tech/free-music-samples-royalty-free-loops-hits-and-multis-to-download-sampleradar
- US presidential speech https://millercenter.org/the-presidency/presidential-speeches
- Ireland presidential speeches https://president.ie/en/media-library/audio
- Movie Quotes: https://movie-sounds.org/
- Poetry: https://www.poetryoutloud.org/listen-to-poems/
- Bird sounds https://www.xeno-canto.org/
- Classical music archive https://freemusicarchive.org/genre/Classical
- Drum loops https://samples.landr.com/collections/free-drum-loops-breaks
- Wikiloops drums https://www.wikiloops.com/tracks/Drums.php
- Loops https://soundcamp.org/
- Library of Congress Citizen DJ https://citizen-dj.labs.loc.gov/